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Vertical Distribution and Community Structure of Meiofauna in Wakod Dam, Maharashtra, India

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Abstract: Freshwater reservoir sediments support diverse meiofaunal communities that respond to sedimentary, hydrological and physicochemical conditions. The present study assessed the taxonomic composition, abundance, vertical distribution and community structure of meiofauna in Wakod Dam, Maharashtra, India. Sampling was conducted at four sites representing inlet, central, dam-wall and anthropogenically influenced littoral conditions during pre-monsoon, monsoon and post-monsoon periods. Sediment cores were divided into four depth intervals: 0–2, 2–5, 5–10 and 10–20 cm. Meiofauna were extracted, identified morphologically and expressed as individuals per 10 cm³ of sediment. Nematoda and Harpacticoida were the principal groups recorded. The inlet site showed the highest reported seasonal abundance, with abundance generally greater during the monsoon than during pre- and post-monsoon periods. Most meiofauna occurred within the upper 5 cm of sediment, with 52.6% recorded at 0–2 cm and 34.8% at 2–5 cm. Nematoda showed the broadest vertical distribution, whereas Gastrotricha, Rotifera and Harpacticoida were strongly concentrated near the sediment surface. Site I exhibited the highest reported taxon richness and Shannon diversity, whereas Site III showed lower diversity and stronger nematode dominance. Spearman correlations indicated positive associations of total abundance and Harpacticoida with dissolved oxygen and redox potential, while suspended solids and phosphate showed negative associations with total abundance. The findings demonstrate clear spatial, seasonal and vertical structuring of reservoir meiofaunal communities and indicate their potential value as complementary biological indicators of sedimentary environmental conditions.

Keywords: freshwater reservoir; meiofauna; Wakod Dam; vertical distribution; Nematoda; Harpacticoida; sediment ecology.

I. INTRODUCTION

Freshwater reservoirs are dynamic ecosystems in which hydrological fluctuations, sediment deposition, organic matter accumulation and anthropogenic inputs influence benthic communities. Meiofauna comprise small metazoans inhabiting aquatic sediments and include nematodes, copepods, rotifers, gastrotrichs, ostracods and other microscopic groups. They occur widely in inland waters and contribute to the functioning and biodiversity of freshwater ecosystems (Giere, 2009; Gansfort *et al.*, 2020; Majdi *et al.*, 2020; Chertoprud and Novichkova, 2023). Recent reviews have emphasized that freshwater meiofauna are useful organisms for examining patterns of biodiversity, community structure and ecological responses to environmental gradients.

Meiofauna occupy important positions in aquatic food webs and participate in nutrient cycling and energy transfer between microorganisms and larger benthic organisms. Their abundance, composition and functional characteristics may vary with sediment properties, oxygen availability, organic matter, hydrological conditions and seasonal changes (Hakenkamp and Morin, 2000; Majdi *et al.*, 2020; Schmid-Araya *et al.*, 2020; Cifoni *et al.*, 2021). Studies of lake littoral meiofauna indicate that Nematoda and Copepoda are among the most frequently investigated groups and that abundance, diversity and community composition are commonly used to characterize meiofaunal assemblages.

Meiofaunal communities can also respond to environmental disturbance and therefore have potential as complementary biological indicators. Their high abundance, diversity and relatively limited mobility allow community-level responses to environmental variation to be detected at relatively small spatial scales (Moens *et al.*, 2022; Ridall and Ingels, 2021). Nematode-based approaches have additionally been investigated for assessment of freshwater sediment quality (Brückner-Hüttemann *et al.*, 2021).

Vertical distribution is another important component of meiofaunal ecology. The upper sediment layers generally provide greater access to oxygen, microbial biomass and recently deposited organic material, whereas deeper sediment may exhibit different redox and resource conditions. Consequently, meiofaunal abundance and taxonomic composition can vary substantially with sediment depth (Giere, 2009). The distribution of meiofaunal groups in lake littoral sediments is influenced by environmental gradients and biological traits, although several aspects of freshwater meiofaunal ecology remain insufficiently studied (Cifoni *et al.*, 2021).

Wakod Dam is an important freshwater reservoir in the Chhatrapati Sambhajnagar region of Maharashtra. However, information on the composition, abundance and vertical distribution of meiofauna in this reservoir remains limited.

The present study therefore aimed to (i) document the major meiofaunal groups occurring at different sites of the reservoir, (ii) examine seasonal and spatial variation in abundance, and (iii) determine vertical distribution and relationships between meiofaunal assemblages and selected environmental variables.

II. MATERIALS AND METHODS

1) Study Area: The study was conducted in Wakod Dam, located in Phulambri region of Chhatrapati Sambhajnagar District (Latitude 20.168°, Longitude 75.4648°), Maharashtra, India. Four sampling locations representing different environmental conditions were selected:

- **Site I:** Inlet region
- **Site II:** Central reservoir region
- **Site III:** Dam-wall region
- **Site IV:** Anthropogenically influenced littoral region

These locations were selected to represent differences in sediment deposition, water movement and human influence.

2) Sampling Design: Samples were collected during three seasonal periods: Pre-monsoon, Monsoon, Post-monsoon. Sediment samples were collected using a cylindrical benthic sediment corer. Each sediment core was sectioned into four depth intervals viz. 0–2 cm, 2–5 cm, 5–10 cm, 10–20 cm

3) Collection and Processing of Meiofauna: Sediment samples were processed for separation of meiofaunal organisms using washing, sieving and appropriate flotation/decantation procedures. The retained organisms were examined microscopically and assigned to major taxonomic groups based on available morphological characters.

Because the original record does not provide sufficient information to independently verify exact corer dimensions, extraction volume, extraction efficiency and subsampling procedures, these details should be inserted from the laboratory/field records before final submission. The same applies to species-level identifications where diagnostic characters were not recorded.

4) Identification and Enumeration: Meiofaunal organisms were identified to the lowest practical taxonomic level supported by morphological examination. Major groups recorded included Nematoda, Harpacticoida, Rotifera, Ostracoda, Gastrotricha, Cladocera, Turbellaria, Tardigrada and juvenile/small Oligochaeta.

Abundance was expressed as individuals per 10 cm³ of sediment using:

$$\text{Meiofaunal density} = \frac{\text{Number of organisms counted}}{\text{Volume of sediment examined}} \times 10$$

Where density is expressed as individuals per 10 cm³ sediment.

a) Environmental Variables

Selected physicochemical variables, including dissolved oxygen, redox potential, chlorophyll-*a*, suspended solids, phosphate and organic carbon, were considered in relation to meiofaunal abundance and community characteristics.

Water-quality measurements should be reported according to the exact analytical procedures used in the laboratory. Where applicable, standard procedures described in *Standard Methods for the Examination of Water and Wastewater* were followed (Baird *et al.*, 2017).

b) Statistical Analysis

Meiofaunal abundance was compared descriptively among sites, seasons and sediment depths. Community characteristics were assessed using taxon richness, Shannon diversity index (*H'*), Pielou's evenness (*J'*), maturity index and nematode:copepod ratio.

Spearman rank correlation coefficients were calculated to examine relationships between selected environmental variables and meiofaunal abundance/community characteristics.

III. RESULTS AND DISCUSSION

A. Taxonomic Composition

Nine major meiofaunal groups were recorded across the four sampling sites. Nematoda and Harpacticoida were present at all sites and represented the principal components of the meiofaunal assemblage.

Rotifera occurred at Sites I, II and IV but were not recorded at Site III. Ostracoda were present at all four sites. Gastrotricha and Cladocera occurred mainly at Sites I and II, with Cladocera also recorded at Site IV. Turbellaria and Tardigrada were recorded only at Site I. Juvenile/small Oligochaeta were recorded at all four sites.

Table 1. Occurrence of major meiofaunal groups at the four sampling sites

Meiofaunal group	Site I	Site II	Site III	Site IV
Nematoda	+	+	+	+
Harpacticoida	+	+	+	+
Rotifera	+	+	—	+
Ostracoda	+	+	+	+
Gastrotricha	+	+	—	—
Cladocera	+	+	—	+
Turbellaria	+	—	—	—
Tardigrada	+	—	—	—
Juvenile/small Oligochaeta	+	+	+	+

B. Seasonal and Spatial Variation in Abundance

Marked spatial and seasonal variation was observed in total meiofaunal abundance. Site I showed the highest reported seasonal abundance, particularly during the monsoon period, when abundance reached $52,864 \pm 7,920$ individuals/10 cm³. Site II showed an abundance of $34,128 \pm 5,040$ individuals/10 cm³ during the monsoon. The lowest abundance was recorded at Site III, where monsoon abundance was $12,064 \pm 1,680$ individuals/10 cm³. Site IV showed intermediate abundance, reaching $28,736 \pm 4,128$ individuals/10 cm³ during the monsoon.

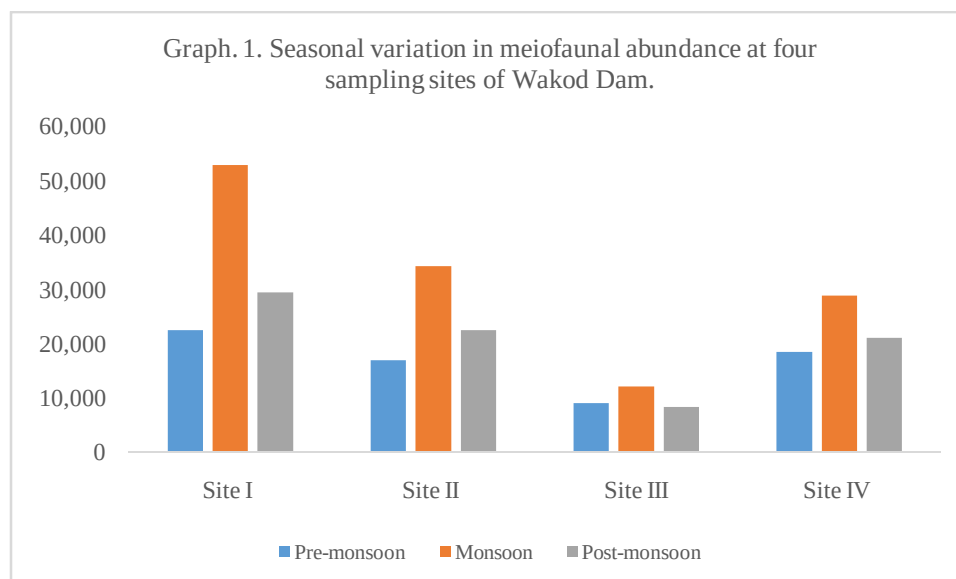
The present study demonstrated substantial spatial variation in meiofaunal abundance among the four sampling locations. The inlet region showed the highest reported abundance, whereas the dam-wall region supported the lowest abundance. Such spatial differences may arise from variation in sediment deposition, organic matter availability, water movement and habitat heterogeneity. Freshwater meiofaunal communities are known to respond to local environmental conditions as well as spatial processes operating across aquatic habitats (Gansfort *et al.*, 2020).

The relatively high abundance at the inlet may be associated with greater deposition of fine sediment and organic material transported into the reservoir. In contrast, the lower abundance at the dam-wall site may reflect differences in sediment characteristics and resource availability. However, these explanations should be considered as ecological interpretations rather than demonstrated causal relationships because sediment grain size, organic matter and other potentially influential variables were not presented at replicate level.

Seasonal variation was also evident, with abundance generally highest during the monsoon. Seasonal changes in water level, oxygen availability, temperature, nutrient dynamics and sediment conditions can influence meiofaunal communities in lake environments (Cifoni *et al.*, 2021). Increased water inflow during the monsoon may transport organic particles and fine sediments into the reservoir and modify benthic habitat conditions. Seasonal variation in freshwater meiofaunal abundance is expected because hydrology and resource availability influence benthic communities.

Table 2. Seasonal abundance of meiofauna at different sampling sites

Site	Pre-monsoon (ind./10 cm ³)	Monsoon (ind./10 cm ³)	Post-monsoon (ind./10 cm ³)
Site I	$22,440 \pm 3,128$	$52,864 \pm 7,920$	$29,338 \pm 4,128$
Site II	$16,824 \pm 2,416$	$34,128 \pm 5,040$	$22,416 \pm 3,216$
Site III	$8,928 \pm 1,248$	$12,064 \pm 1,680$	$8,256 \pm 1,152$
Site IV	$18,416 \pm 2,688$	$28,736 \pm 4,128$	$20,928 \pm 3,024$



C. Vertical Distribution

Meiofaunal organisms were concentrated predominantly in the upper sediment layers. Across all groups, **52.6%** of the recorded abundance occurred in the 0–2 cm layer and a further **34.8%** occurred in the 2–5 cm layer. Thus, approximately **87.4%** of the recorded meiofauna occurred within the upper 5 cm.

Nematoda showed the broadest vertical distribution, with 58.2% at 0–2 cm and 32.4% at 2–5 cm. Harpacticoida were particularly concentrated near the sediment surface, with 88.1% occurring in the 0–2 cm layer. Gastrotricha showed the strongest surface concentration, with 94.6% at 0–2 cm.

A major pattern in the present study was the strong concentration of meiofauna in the upper sediment layers. Approximately 87.4% of the total recorded meiofaunal abundance occurred within the upper 5 cm.

The predominance of meiofauna in surface sediment is ecologically plausible because the sediment–water interface provides access to oxygen, microbial production and recently deposited organic material. Meiofaunal distribution is consequently influenced by interactions among sediment characteristics, food resources and physicochemical gradients (Giere, 2009; Majdi *et al.*, 2020). Freshwater meiofaunal studies also demonstrate that different taxa may exhibit distinct responses to environmental gradients because of differences in feeding strategy, substrate association and life-history characteristics (Cifoni *et al.*, 2021).

Harpacticoida, Rotifera and Gastrotricha showed particularly strong surface concentration, whereas Nematoda extended relatively deeper into the sediment. The broader vertical distribution of nematodes may be associated with their diverse feeding strategies and ability to occupy a wide range of sedimentary microhabitats. Meiofaunal trophic ecology is complex, and diet may include bacteria, fungi, algae, protists and other small organisms (Majdi *et al.*, 2020).

Nevertheless, the present study should not interpret deeper occurrence of nematodes alone as evidence of specific physiological tolerance or pollution adaptation without species-level identification and supporting environmental measurements.

Table 3. Vertical distribution of major meiofaunal groups

Taxon	0–2 cm (%)	2–5 cm (%)	5–10 cm (%)	10–20 cm (%)
Nematoda	58.2	32.4	6.8	2.6
Harpacticoida	88.1	8.4	2.1	1.4
Rotifera	92.3	5.6	1.8	0.3
Ostracoda	76.4	18.2	4.6	0.8
Gastrotricha	94.6	4.2	1.2	0.0
Cladocera	89.2	7.8	2.4	0.6
All groups	52.6	34.8	9.2	3.6

D. Diversity and Community Structure

Site I exhibited the highest reported taxon richness, Shannon diversity and Pielou's evenness. Site III showed the lowest taxon richness and diversity values.

The nematode:copepod ratio was lowest at Site I and highest at Site III, indicating stronger relative dominance of nematodes at the dam-wall site.

Site I exhibited the highest reported taxon richness, Shannon diversity and evenness, whereas Site III had lower richness and diversity. The difference suggests that meiofaunal community structure varies considerably across the reservoir.

The higher nematode:copepod ratio at Site III indicates greater relative dominance of nematodes at this location. However, the nematode:copepod ratio should be treated as a descriptive community metric rather than a universal pollution index because it can be influenced by sediment type, season, sampling methodology and taxonomic resolution.

The maturity index was also lower at Site III. The maturity index was originally developed as a nematode-based ecological measure related to disturbance and colonizer–persister composition (Bongers, 1990). In the present study, however, the index should be interpreted comparatively among the sampled sites rather than assigned to fixed pollution categories.

Table 4. Community characteristics at the four sampling sites

Parameter	Site I	Site II	Site III	Site IV
Taxon richness	28	22	12	20
Shannon diversity (H')	2.68	1.92	1.42	1.78
Pielou's evenness (J')	0.78	0.62	0.52	0.58
Maturity index	2.42	2.18	1.68	1.82
Nematode:copepod ratio	3.8	6.2	14.2	9.8
Trophic diversity index	0.68	0.52	0.32	0.42

The maturity index values should be interpreted cautiously because the ecological meaning of the index depends on the taxonomic resolution and assignment of nematode taxa to colonizer–persister categories. The original maturity index concept was developed as a nematode-based measure of ecological disturbance (Bongers, 1990).

E. Relationships with Environmental Variables

Spearman correlation coefficients indicated positive relationships between dissolved oxygen and total meiofaunal abundance, Harpacticoida abundance and Shannon diversity. Redox potential showed a similar pattern.

Suspended solids showed negative relationships with total abundance, Harpacticoida abundance and Shannon diversity. Phosphate was negatively associated with total abundance, Harpacticoida and Shannon diversity but showed a weak positive association with nematode abundance. Organic carbon showed a strong positive association with nematode abundance.

Positive correlations of total meiofaunal abundance and Harpacticoida with dissolved oxygen and redox potential suggest that oxygenated sediment conditions may be associated with greater abundance and diversity of several meiofaunal groups. Similar associations are ecologically plausible because meiofauna occupy sedimentary microhabitats where oxygen availability and organic matter influence microbial and metazoan communities.

The negative association of suspended solids with total abundance and diversity may reflect changes in sediment structure or habitat conditions. Similarly, the negative association of phosphate with several community measures could indicate a relationship with nutrient enrichment; however, correlation alone cannot establish that phosphate caused the observed community patterns.

The positive relationship between organic carbon and nematode abundance is ecologically plausible because organic matter supports microbial production and provides food resources for organisms within the sediment food web. Meiofauna contribute to aquatic food-web processes and can influence microbial and organic-matter dynamics (Hakenkamp & Morin, 2000; Schmid-Araya *et al.*, 2020).

Therefore, the correlations reported here should be regarded as evidence of association rather than causation.

Table 5. Spearman correlation coefficients between environmental variables and meiofaunal characteristics

Environmental variable	Total abundance	Nematoda	Harpacticoida	Shannon diversity
Dissolved oxygen	0.73	0.42	0.81	0.69
Redox potential	0.68	0.38	0.76	0.64
Chlorophyll- <i>a</i>	0.62	0.29	0.72	0.58
Suspended solids	−0.59	−0.21	−0.68	−0.54

Phosphate	-0.54	0.18	-0.62	-0.49
Organic carbon	0.47	0.82	0.12	0.31

The present study demonstrates that meiofaunal communities provide information at several ecological scales. Spatial differences among the four sampling sites demonstrate heterogeneity within the reservoir, while seasonal differences indicate temporal variability. The strong concentration of organisms within the upper sediment layers highlights the importance of sampling depth when evaluating reservoir meiofaunal communities. Nematoda and Harpacticoida were consistently recorded across the reservoir and may therefore represent useful focal groups for future monitoring. However, more detailed taxonomic resolution would improve ecological interpretation. Species-level identification, functional feeding groups, sediment grain-size analysis, organic matter measurements and standardized replication would provide a stronger basis for assessing meiofaunal responses to environmental gradients. Freshwater meiofauna are increasingly recognized as useful organisms for understanding ecological processes and spatial community structure. Reviews of freshwater meiofaunal ecology emphasize their roles in food webs, production and spatial community dynamics (Gansfort *et al.*, 2020; Schmid-Araya *et al.*, 2020).

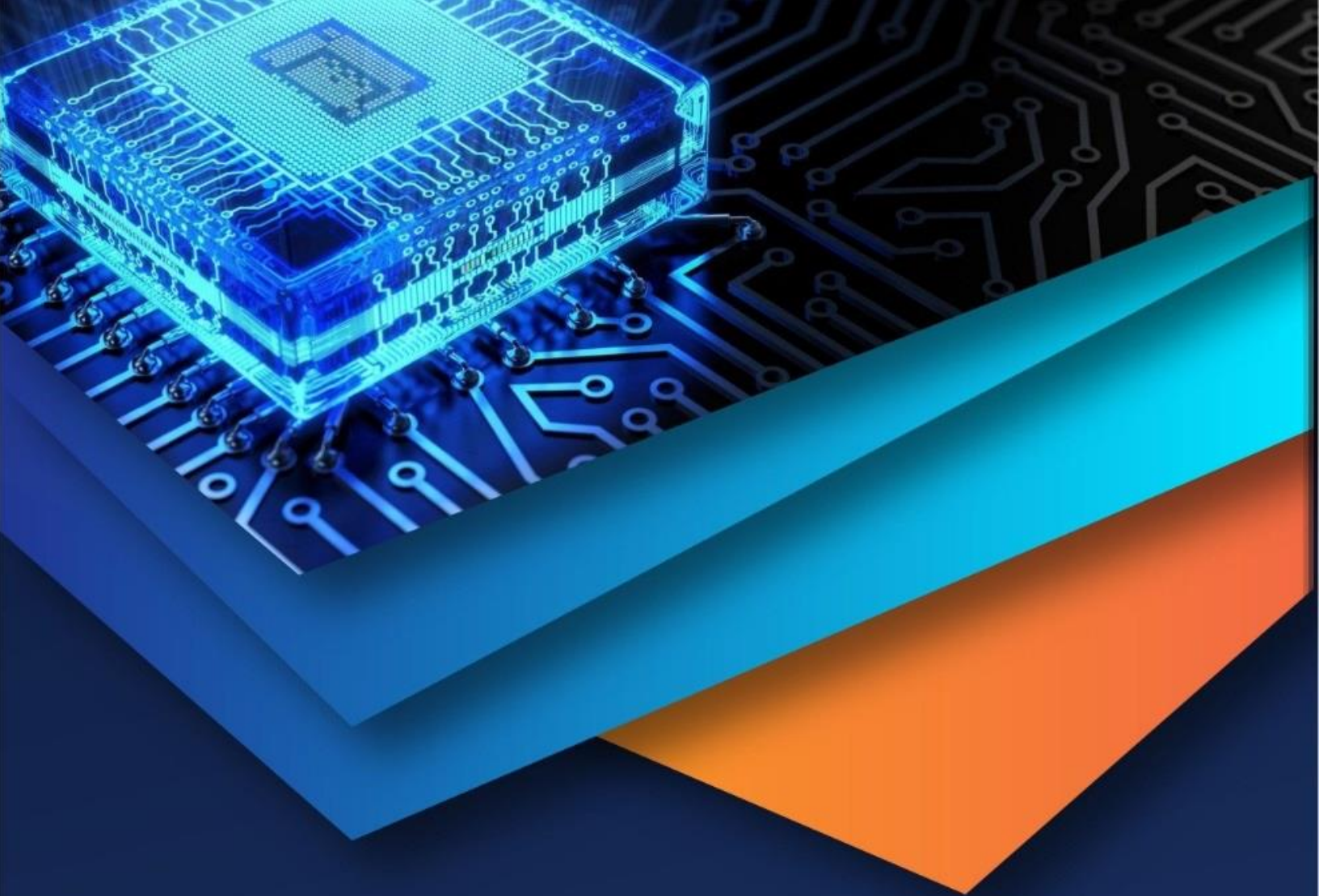
IV. CONCLUSION

The study demonstrated clear spatial, seasonal and vertical structuring of meiofaunal communities in Wakod Dam. Nematoda and Harpacticoida were the principal meiofaunal groups and were recorded at all sampling sites. The inlet region exhibited the highest reported seasonal abundance, while the dam-wall site showed lower abundance and diversity. Approximately 87.4% of the recorded meiofaunal abundance occurred within the upper 5 cm of sediment, demonstrating strong vertical concentration near the sediment surface. Site I showed the highest reported taxon richness, Shannon diversity and evenness, whereas Site III exhibited lower diversity and stronger nematode dominance. Positive associations with dissolved oxygen and redox potential and negative associations with suspended solids and phosphate indicate relationships between meiofaunal community characteristics and environmental conditions.

Overall, meiofauna show potential as a complementary biological component for assessing spatial and seasonal ecological variation in reservoir sediments. However, confirmation using replicate-level data, standardized sampling, detailed taxonomic identification and appropriate inferential statistics is required before the numerical results are used for definitive environmental assessment.

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